CSE543 Computer and Network Security

Module: Network Security

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Networking

• Fundamentally about transmitting information between two devices
• Direct communication is now possible between any two devices anywhere (just about)
  ‣ Lots of abstraction involved
  ‣ Lots of network components
  ‣ Standard protocols
  ‣ Wired and wireless
  ‣ Works in *protection* environment
• What about ensuring *security*?
The network ...

Internet

LAN

(remote hosts/servers) (hosts/desktops)

(edge) (perimeter)

(server)
The big picture ....

• Internet Protocol (IP)
  ‣ Really refers to a whole collection of protocols making up the vast majority of the Internet

• Routing
  ‣ How these packets move from place to place

• Network management
  ‣ Administrators have to maintain the services and infrastructure supporting everyone’s daily activities
Network Security

• Every machine is connected
  ‣ What is trust model of the network?

• Not just limited to dogs as users
  ‣ What other ‘dogs’ are out there?
Network security: the high bits

• The network is …
  ‣ … a collection of interconnected computers
  ‣ … with resources that must be protected
  ‣ … from unwanted inspection or modification
  ‣ … while maintaining adequate quality of service.

• Another way of seeing network security is …
  ‣ … securing the network infrastructure such that the integrity, confidentiality, and availability of the resources is maintained.
The End-to-End Argument

• Clark et al. discussed a property of good systems that says features should be placed as close to resources as possible
  ‣ In communication, this means that we want the middle of the network to be simple, and the end-points to be smart (e.g., do everything you can at the end-points)
    • “Dumb, minimal network”
  ‣ This is the guiding principle of IP (Internet)
  ‣ Q: Does this have an effect on security?

• Note: this is a departure from the early networks which smart network, dumb terminals
Exploiting the network ...

• The Internet is extremely vulnerable to attack
  ‣ it is a huge open system ...
  ‣ which adheres to the end-to-end principle
    • smart end-points, dumb network

• Can you think of any large-scale attacks that would be enabled by this setup?
Security Problems in the TCP/IP Protocol Suite

• Bellovin’s observations about security problems in IP
  ‣ Not really a study of how IP is misused, e.g., IP addresses for authentication, but really what is inherently bad about the way in which IP is setup

• A really, really nice overview of the basic ways in which security and the IP design is at odds (circa 1989)
TCP/IP uses a three-way handshake to establish a connection:

1. C -> S: \( Q_C \)
2. S -> C: \( Q_S, \text{ack}(Q_C) \) where sequence number \( Q_S \) is nonce
3. C -> S: \( \text{ack}(Q_S) \) … then send data

However assume the bad guy does not hear msg 2, if he can guess \( Q_S \), then he can get S to accept whatever data it wants (useful if doing IP authentication, e.g., “rsh”)
Sequence Number Prediction (fixes)

- The only way you really fix this problem to stop making the sequence numbers predictable:
  - Randomize them -- you can use DES or some other mechanism to generate them randomly
  - There is an entire sub-field devoted to the creation and management of randomness in OSes
- Also, you could look for inconsistencies in timing information
  - Assumption: the adversary has different timing
  - OK, may be helpful, but far from definitive
What’s Changed?

• Collaborative TCP Sequence Number Inference Attack -- How to Crack Sequence Number Under A Second
  Zhiyun Qian, Z. Morley Mao, Yinglian Xie
  *In Proceedings of ACM Conference on Computer and Communications Security (CCS) 2012, Raleigh, NC.*

• Off-Path TCP Sequence Number Inference Attack -- How Firewall Middleboxes Reduce Security
  Zhiyun Qian, Z. Morley Mao

• Still have TCP sequence number attacks
Internet Control Message Protocol (ICMP)

• **ICMP** is used as a control plane for IP messages
  ‣ Ping (connectivity probe)
  ‣ Destination Unreachable (error notification)
  ‣ Time-to-live exceeded (error notification)

• These are largely indispensable tools for network management and control
  ‣ Error notification codes can be used to reset connections without any authentication

• Solution: verify/sanity check sources and content
  ‣ ICMP “returned packets”

• Real solution: filter most of ICMP, ignore it
Address Resolution Protocol (ARP)

• Protocol used to map IP address onto the physical layer addresses (MAC)
  1) ARP request: who has x.x.x.x?
  2) ARP response: me!
• Policy: last one in wins
• Used to forward packets on the appropriate interfaces by network devices (e.g., bridges)

• Q: Why would you want to spoof an IP address?
ARP poisoning

• Attack: replace good entries with your own
• Leads to
  ‣ Session hijacking
  ‣ Man-in-the-middle attacks
  ‣ Denial of service, etc.

• Lots of other ways to abuse ARP.
• Nobody has really come up with a good solution
  ‣ Except smart bridges, routers that keep track of MACs
• However, some not worried
  ‣ If adversary is in your perimeter, you are in big trouble
  ‣ You should validate the source of each packet independently
• Post office protocol - mail retrieval
  ‣ Passwords passed in the clear (duh)
  ‣ Solution: SSL, SSH, Kerberos

• Simple mail transport protocol (SMTP) - email
  ‣ Nothing authenticated: SPAM
  ‣ Nothing hidden: eavesdropping
  ‣ Solution: your guess is as good as mine

• File Transfer protocol - file retrieval
  ‣ Passwords passed in the clear (duh)
  ‣ Solution: SSL, SSH, Kerberos
DNS - The domain name system

• DNS maps between IP address (12.1.1.3) and domain and host names (ada.cse.psu.edu)

  ‣ How it works: the “root” servers redirect you to the top level domains (TLD) DNS servers, which redirect you to the appropriate sub-domain, and recursively ....
  
  ‣ Note: there are 13 “root” servers that contain the TLDs for .org, .edu, and country specific registries (.fr, .ch)
A DNS query

ISP Nameserver

User PC

1. www.patrickmcdaniel.org?

8. 207.140.168.131

2. www.patrickmcdaniel.org?

3. redirect

4. www.patrickmcdaniel.org?

5. redirect

6. www.patrickmcdaniel.org?

7. 207.140.168.131

a-root-servers.net

a.gtld-servers.org

ns-patrickmcdaniel.org
A DNS query

ISP Nameserver

User PC

DNS Cache
www.patrickmcdaniel.org = 207.140.168.131

1. www.patrickmcdaniel.org?
2. www.patrickmcdaniel.org?
3. redirect
4. www.patrickmcdaniel.org?
5. redirect
6. www.patrickmcdaniel.org?
7. 207.140.168.131
8. 207.140.168.131
“Glue” information

• Suppose you ask a name server for a record and it redirects you to another name server (NS record)
  ‣ e.g., if you ask a root for a NS (name server) record for NET, it returns NS records for the authoritative servers for .net

• It will also give you the A (resource) record for the authoritative servers you were directed to
  ‣ avoid looking them up
  ‣ This is known as the “glue” records

```cpp
.NET referrals
/* Authority section */
NET. IN NS A.GTLD-SERVERS.NET.
IN NS B.GTLD-SERVERS.NET.
IN NS C.GTLD-SERVERS.NET.
... IN NS M.GTLD-SERVERS.NET.

/* Additional section - "glue" records */
A.GTLD-SERVERS.net. IN A 192.5.6.30
B.GTLD-SERVERS.net. IN A 192.33.14.30
C.GTLD-SERVERS.net. IN A 192.26.92.30
... M.GTLD-SERVERS.net. IN A 192.55.83.30
```
Nothing is authenticated, so really the game is over
- You cannot really trust what you hear …
- But, many applications are doing just that.
- Spoofing of DNS is really dangerous

Moreover, DNS is a catalog of resources
- Zone-transfers allow bulk acquisition of DNS data
- … and hence provide a map for attacking the network

Lots of opportunity to abuse the system
- Relies heavily on caching for efficiency -- cache pollution
- Once something is wrong, it can remain that way in caches for a long time (e.g., it takes a long time flush)
- Data may be corrupted before it gets to authoritative server
A Cache Poisoning Attack

• All requests have a unique query ID
• The nameserver/resolver uses this information to match up requests and responses
• If an adversary can guess the query ID, then it can forge the responses and pollute the DNS cache
  ‣ 16-bit query IDs (not hard)
  ‣ Some servers increment IDs (or use other bad algo.)
  ‣ First one in wins!!!
• Note: If you can observe the traffic going to a name server, you can pretty much arbitrarily own the Internet for the clients it serves.
Kaminsky DNS Vulnerability

1. Query a random host in a victim zone, e.g., 1234.cse.psu.edu

2. Spoof responses* as before, but delegate authority to some server which you own.
   1. The glue records you give make you authoritative

3. You now own the domain.

*the original attack exploited poor ID selection
Kaminski Fixes

• Make the ID harder to guess (randomized ports)
  ‣ Amplified ID space from $2^{16}$ to $2^{27}$

• Prevent foreign requests from being processed
  ‣ E.g., filter requests from outside domain

• Observe and filter conflicting requests
  ‣ E.g., if you see a lot of bogus looking requests, be careful

• All of this treats the symptoms, not the disease.
  ‣ Lack of authenticated values
  ‣ Thus, if you can observe request traffic, prevent legitimate responses, or are just plain patient, you can mount these attacks.
Other Issues (Bailey et al)

- **DNS Resolvers**
  - Amplification attacks - Spoof IP address of DNS requestor
  - Disable recursive DNS resolution
- **A and PTR records**
  - Malicious IPs often have inconsistent A and PTR records
  - Make PTR records consistent with A records
- **BGP Misconfiguration**
  - Border Gateway Protocol (BGP) to exchange advertised routes
  - New route announcements should be infrequent and long-lived
- **Egress Filtering**
  - Prevent IP address spoofing by filtering egress packets not from inside your network
Configuration Guidelines

• Well-documented in published Request for Comments (RFCs) and Best Current Practices (BCPs)

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TABLE I. SUMMARY OF MISMANAGEMENT METRICS AND THE THIRD-PARTY, PUBLIC DATA SOURCES USED FOR VALIDATION
• A standard-based (IETF) solution to security in DNS
  ‣ Prevents data spoofing and corruption
  ‣ Public key based solution to verifying DNS data
  ‣ Authenticates
    • Communication between servers
    • DNS data
      ‣ content
      ‣ existence
      ‣ non-existence
    • Public keys (a bootstrap for PKI?)
DNSSEC Mechanisms

• Securing the DNS records
  ‣ Each domain signs their “zone” with a private key
  ‣ Public keys published via DNS
  ‣ *Indirectly* signed by parent zones
  ‣ Ideally, you only need a self-signed root, and follow keys down the hierarchy

```
root ----> .edu ----> psu.edu ----> cse.psu.edu
```

Signs

Signs

Signs
DNSSEC Mechanisms

• **TSIG**: transaction signatures protect DNS operations
  ‣ Zone loads, some server to server requests (master -> slave), etc.
  ‣ Time-stamped signed responses for dynamic requests
  ‣ A misnomer -- it currently uses shared secrets for TSIG (HMAC) or do real signatures using public key cryptography

• **SIG0**: a public key equivalent of TSIG
  ‣ Works similarly, but with public keys
  ‣ Not as popular as TSIG

• Note: these mechanisms assume clock sync. (NTP)